

## **FLAT PLATE HEAT TRANSFER DEVICE AND METHOD FOR MANUFACTURING THE SAME**

### TECHNICAL FIELD

5        The present invention relates to a flat plate heat transfer device capable of emitting heat from a heat source by circulating a working fluid using evaporation and condensation and its manufacturing method, and more particularly to a flat plate heat transfer device capable of preventing crush of a flat case and giving vapor dispersion channels and liquid flow channels in a direction that ensures a maximum heat transfer  
10      efficiency and its manufacturing method.

### BACKGROUND ART

15      In recent, an electronic equipment such as notebook or PDA becomes smaller and thinner along with the development of integration technique. In addition, together with the increased demands for higher responsiveness of an electronic equipment and improvement of functions, energy consumption is also tending increased. Accordingly, much heat is generated from electronic components in the electronic equipment while the equipment is operated, so various flat plate heat transfer devices are used to emit the heat outside.

20      As a traditional example of the conventional flat plate heat transfer device, a heat pipe is widely known in the art. The heat pipe is configured so that an inside of a sealed container is decompressed in a vacuum so as to be isolated from an ambient air, and then the container is sealed after a working fluid is injected therein. As for its operation, a working fluid is heated and evaporated near the heat source to which the heat  
25      pipe is installed, and then flowed to a cooling part. At the cooling part, the vapor is condensed into a liquid again with emitting heat outside, and then returns to its original

position. By means of such working fluid circulating mechanism, the heat generated in the heat source is emitted outside, so the temperature of the electronic component may be kept in a suitable level accordingly.

US 5,642,775 issued to Akachi et al. discloses a plate heat pipe including a plate with minute channels called capillary tunnel and formed by an extrusion method, and a working fluid filled therein. If one end of the plate is heated, the working fluid is heated and evaporated into a vapor and then moved to the other end of each channel, and then cooled and condensed again and moved to a heating part. The plate heat pipe of Akachi et al. may be adopted between a motherboard and a printed circuit card. However, forming a plurality of such small and fine capillary channels by means of extrusion is very difficult.

US 5,309,986 issued to Itoh discloses an air-sealed rectangular container and a heat carrier (working fluid) filled in the container. In the patent, an inclined groove is formed on an inner surface of the container, and the container has pointed corners so that a condensed working fluid may be evenly distributed in the entire region of the container, which accordingly enables to effectively absorb and emit heat.

US 6,148,906 issued to Li et al. discloses a flat plate heat pipe for delivering heat from a heat source positioned in an electronic equipment enclosure to an external heatsink. The flat plate heat pipe includes a metallic bottom plate having a depression therein containing a set of rods and a top plate for covering the bottom plate. The space restricted by the bottom plate, the top plate and the rods is decompressed and filled with a working fluid. As mentioned above, the working fluid absorbs heat from a heating part in the channel and then moves to a cooling part, and the working fluid condensed with emitting heat in the cooling part is circulated again to the heating part so that the equipment is cooled.

FIG. 1 shows a heat dispersion unit 10 installed between a heat source 20 and a heatsink 30, which is another example of a conventional cooling device. The heat dispersion unit 10 is configured so that a working fluid is filled in an inner space 40 of a thin metallic case 50, and a wick structure 60 is formed on an inner surface of the 5 metallic case 50. The heat generated in the heat source 20 is delivered to the wick structure 60 in the heat dispersion unit 10 contacted with the heat source 20. In this region, the working fluid contained in the wick structure 60 is evaporated and dispersed in all directions through the inner space 40, and then condensed with emitting heat at the wick structure 60 in a cooling region to which the heatsink 30 is installed. The heat 10 emitted in this condensation process is delivered to the heatsink 30, and then emitted outward by means of forced convection by a cooling fan 70.

Such cooling devices should have a sufficient space for the vapor to flow since the working fluid in a liquid state should be evaporated with absorbing heat from the heat source and the evaporated vapor should be moved again to the cooling region. 15 However, it is not easy to have a sufficient vapor dispersion channel in the flat case of the flat plate heat transfer device with small thickness. In particular, since the flat case is kept in a vacuous state (or, a decompressed state), the upper and lower plates of the case are apt to be crushed or distorted during its manufacturing procedure, thereby deteriorating reliability of the product.

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#### DISCLOSURE OF INVENTION

The present invention is designed to solve the problems of the prior art, and therefore it is an object of the present invention to provide an improved flat plate heat transfer device with a geometric structure that is capable of preventing distortion of the 25 device to ensure reliability of product by firmly supporting a flat case of the flat plate

heat transfer device that becomes thinner, and also giving a vapor dispersion channel and a liquid flow channel in an optimized direction for effective heat transfer.

In order to accomplish the above object, the present invention provides a flat plate heat transfer device, one end of which is contacted with a heat source and the other end 5 of which is contacted with a heat emitting unit, the device transferring heat generated at the heat source to the heat emitting unit in a horizontal direction, the device including a thermally-conductive flat case containing a working fluid that is evaporated with absorbing heat from the heat source and condensed with emitting heat to the heat emitting unit; and a mesh aggregate installed in the case and configured so that coarse 10 mesh and fine mesh in which wires are woven to be alternately crossed up and down are vertically laminated with being contacted with each other, wherein the coarse mesh provides main-directional and sub-directional vapor dispersion channels with different sectional areas at each crossing point of mesh wires so that vapor evaporated from the working fluid is capable of flowing therethrough, the main-directional vapor dispersion 15 channel with a relatively larger sectional area being parallel to a heat transfer direction, wherein the fine mesh provides liquid flow channels along a surface of the mesh wires.

Preferably, an opening width [ $M=(1-Nd)/N$ , where N is a mesh number, and d is a wire diameter (inch)] of the coarse mesh is 0.19 to 2.0 mm, the coarse mesh has a wire diameter of 0.17 to 0.5 mm, and the coarse mesh has an opening area of 0.036 to 4.0 20 mm<sup>2</sup>. The coarse mesh also preferably has a mesh number from 10 to 60 on the basis of ASTM specification E-11-95.

Preferably, an opening width [ $M=(1-Nd)/N$ , where N is a mesh number, and d is a wire diameter (inch)] of the fine mesh is 0.019 to 0.18 mm, the fine mesh has a wire diameter of 0.02 to 0.16 mm, and the fine mesh has an opening area of 0.00036 to 0.0324 25 mm<sup>2</sup>. The fine mesh also preferably has a mesh number from 80 to 400 on the basis of

ASTM specification E-11-95.

Preferably, the fine mesh is arranged adjacent to the heat source and the coarse mesh is arranged adjacent to the heat emitting unit.

In one aspect of the invention, the mesh aggregate is configured so that the coarse  
5 mesh is interposed between two layers of fine meshes. At this time, at least one layer  
of additional fine mesh may be further provided in at least a part of the coarse mesh  
interposed between the fine meshes so as to give a liquid channel by interconnecting the  
fine meshes.

In another aspect of the invention, the mesh aggregate is configured so that the  
10 fine mesh, the coarse mesh and an intermediate mesh are subsequently laminated from  
bottom to top. Here, the intermediate mesh has a mesh number relatively larger than  
that of the coarse mesh and relatively smaller than that of the fine mesh. At this time,  
at least one layer of additional fine or intermediate mesh may be further provided in at  
least a part of the coarse mesh interposed between the fine mesh and the intermediate  
15 mesh so as to give a channel by interconnecting the fine mesh and the intermediate mesh.

In still another aspect of the invention, the mesh aggregate is configured to  
include the fine mesh as a lower layer and the coarse mesh and the intermediate mesh as  
an upper layer so that the intermediate mesh is faced with the heat emitting unit. At  
this time, the intermediate mesh may have a vapor flow space so that the vapor  
20 introduced from the coarse mesh flows therein.

According to the present invention, the flat plate heat transfer device may further  
include a wick structure installed in contact with the mesh aggregate and located under  
the mesh aggregate within the case, the wick structure having unevenness on a surface so  
that the working fluid is contained and flowed therein and at the same time evaporated by  
25 means of heat absorbed from the heat source and flowed toward the mesh aggregate.

The wick structure may be formed by sintered copper, stainless steel, or nickel powder, or by etching polymer, silicon, silica, copper, stainless steel, nickel, or aluminum plate. As an alternative, the case may be made of electrolytic copper foil so that an inner surface having prominence and depression is used as the wick structure.

5 According to the present invention, the fine mesh and the intermediate mesh respectively have main-directional and sub-directional liquid flow channels with different sectional areas, and the main-directional liquid flow channel is preferably parallel to a heat transfer direction.

According to the present invention, the working fluid is water, ethanol, ammonia, 10 methanol, nitrogen, or Freon. An amount of filled working fluid is preferably 80 to 150% of wick porosity.

According to the present invention, the mesh is preferably made of metal, polymer, or plastic. Here, the metal includes copper, aluminum, stainless steel, molybdenum, or their alloy.

15 In addition, the case is made of metal, polymer, or plastic, and the metal preferably includes copper, aluminum, stainless steel, molybdenum, or their alloy.

In order to achieve the above object, there is also provided a method for manufacturing a flat plate heat transfer device. At first, upper and lower plates of the flat case are formed, respectively. And then, a mesh aggregate with a structure that 20 coarse mesh, in which wires are woven to be alternately crossed up and down, and fine mesh, in which wires are woven to be alternately crossed up and down, are laminated vertically is inserted into the flat case. Here, the coarse mesh mainly gives vapor dispersion channels, and the fine mesh layer mainly gives liquid flow channels. The coarse mesh has main-directional and sub-directional vapor dispersion channels with 25 different sectional areas at each crossing point of mesh wires so that vapor evaporated

from the working fluid is capable of flowing therethrough, and when the mesh aggregate is inserted into the flat case, it is important to adjust a direction of the coarse mesh so that the main-directional vapor dispersion channels of the coarse mesh are parallel to a heat transfer direction. Subsequently, a flat case is formed by uniting the upper and lower plates with leaving a working fluid injection hole. And then, an inside of the united case is decompressed into a vacuum through the working fluid injection hole and then a working fluid is injected through the working fluid injection hole. Finally, the flat case with the working fluid injected therein is sealed to complete the flat plate heat transfer device.

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#### BRIEF DESCRIPTION OF THE DRAWINGS

Other objects and aspects of the present invention will become apparent from the following description of embodiments with reference to the accompanying drawing in which:

15 FIG. 1 is a sectional view showing a conventional flat plate heat transfer device;

FIG. 2 is a sectional view showing a flat plate heat transfer device according to a preferred embodiment of the present invention;

FIG. 3 is a sectional view showing a flat plate heat transfer device according to another embodiment of the present invention;

20 FIG. 4 is a plane view showing a structure of a coarse mesh adopted according to a preferred embodiment of the present invention;

FIG. 5 is a plane view showing a structure of a fine mesh adopted according to a preferred embodiment of the present invention;

25 FIG. 6 is an enlarged plane view showing a detailed structure of the mesh adopted according to a preferred embodiment of the present invention;

FIG. 7 is a sectional side view showing a vapor dispersion channel formed in the mesh according to a preferred embodiment of the present invention, seen in X direction;

FIG. 8 is a sectional side view showing a vapor dispersion channel formed in the mesh according to a preferred embodiment of the present invention, seen in Y-direction;

5 FIG. 9 is a sectional side view showing a liquid membrane formed in the mesh according to a preferred embodiment of the present invention;

FIG. 10 is a plane view showing a mesh having a liquid membrane similar to FIG. 9;

10 FIGs. 11 to 13 are perspective views showing various appearances of the flat plate heat transfer device according to the present invention;

FIGs. 14 to 16 are sectional views showing various examples of a flat case used in the flat plate heat transfer device according to the present invention;

FIG. 17 is a sectional view showing a flat plate heat transfer device according to still another embodiment of the present invention;

15 FIG. 18 is a sectional view showing a flat plate heat transfer device according to still another embodiment of the present invention;

FIG. 19 is a sectional view showing a flat plate heat transfer device according to still another embodiment of the present invention;

20 FIG. 20 is a sectional view showing a flat plate heat transfer device according to still another embodiment of the present invention;

FIG. 21 is a sectional view showing a flat plate heat transfer device according to still another embodiment of the present invention;

FIG. 22 is a sectional view taken along B-B' line of FIG. 21;

FIG. 23 is a sectional view taken along C-C' line of FIG. 22; and

25 FIG. 24 is a graph showing results of an experiment that is conducted to evaluate

heat transfer performance of the flat plate heat transfer device according to embodiments of the present invention

#### BEST MODES FOR CARRYING OUT THE INVENTION

5       Hereinafter, embodiments are described for specifying the present invention, and detailed description will be provided with reference to the accompanying drawings for better understanding of the invention. However, the embodiments of the present invention may be modified in various ways, and it should not be interpreted that the scope of the invention is limited to the embodiments described below. The 10 embodiments of the invention are provided just for clearer and more definite illustration to those having ordinary skill in the art. In the drawings, the same reference numeral designates the same element.

FIG. 2 is a sectional view showing a flat plate heat transfer device according to a preferred embodiment of the present invention. Referring to FIG. 2, the flat plate heat 15 transfer device 100 of the present invention includes a flat case 130 installed between a heat source 110 and a heat emitting unit 120 such as a heatsink and composed of upper and lower plates 130a and 130b, a mesh aggregate G inserted into the flat case 130, and a working fluid acting as a medium for delivering heat in the flat case 130. Here, the mesh aggregate G is configured so that a fine mesh 140 in which wires are finely woven 20 to be alternately crossed up and down and a coarse mesh 150 in which wires are coarsely woven to be alternately crossed up and down are laminated to be opposite to each other. Herein, it should be understood that the terms ‘fine mesh 140’ and ‘coarse mesh 150’ are defined according to a relative mesh lattice density, and the fine mesh 140 has a larger mesh number than the coarse mesh 150.

25       The flat case 130 is made of metal with excellent thermal conductivity,

conductive polymer, or thermal-conductive plastic so that it may easily absorb heat from the heat source 110 and easily emit heat to the heat emitting unit 120.

FIGs. 4 and 6 are a plane view showing the entire coarse mesh 150 and an enlarged plane view showing a part of the coarse mesh 150 among the meshes of the 5 mesh aggregate G. Referring to FIGs. 4 and 6, the coarse mesh 150 is woven so that widthwise wires 150a and 150b and lengthwise wires 150c and 150d are alternately crossed with each other. Such a coarse mesh 150 may be made of metal, polymer or plastic wire. Preferably, the metal is copper, aluminum, stainless steel, molybdenum, or their alloy. In addition, the coarse mesh 150 may be made in various shapes such as 10 square, rectangle, or other shapes according to a shape of a desired flat case.

FIG. 5 is a plane view showing the entire fine mesh 140 in detail among the meshes of the mesh aggregate G. The fine mesh 140 and the coarse mesh 150 are preferably oppositely contacted to each other. The fine mesh 140 is woven with the same material and using the same way as the aforementioned coarse mesh 150.

15 Meanwhile, the mesh aggregate G of the present invention may be configured as shown in FIG. 3 to include a coarse mesh layer 150L in which three layers of coarse meshes are laminated, and a fine mesh layer 140L in which three layers of fine meshes are laminated. However, the number of layers in the mesh is not limited specially, but may be suitably selected in consideration of cooling capacity of the device or thickness 20 of an electronic equipment.

Referring to FIG. 6 again, a width M of an opening of the mesh 140 and 150 is generally expressed like the following equation 1.

Equation 1

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$$M = (1 - Nd) / N$$

Here,  $d$  is a diameter (inch) of the mesh wire, and  $N$  is a mesh number (the number of lattices existing in a length of 1 inch).

In the present invention, the coarse mesh 150 acts as a means for giving a vapor dispersion channel through which an evaporated working fluid may flow. More specifically, referring to FIG. 7 that shows a sectional side view of a part of the coarse mesh 150, taken along A-A' line of FIG. 6, the coarse mesh 150 is configured in a way that the widthwise wire 150a is contacted with the lower surface of the lengthwise wire 150c, and also contacted with the upper surface of the adjacent lengthwise wire 150d.

Though not shown in the figures, the adjacent widthwise wire 150b shown in FIG. 6 is arranged in a contrary way. At this time, at positions near the upper and lower surfaces of the widthwise wire 150a, empty spaces are generated respectively, and each empty space acts as a vapor dispersion channel Pv. The vapor dispersion channel Pv is formed from a crossing point J of the widthwise wire 150a and the lengthwise wires 150c and 150d along a running direction of the lengthwise wires 150c and 150d, and its sectional area is gradually reduced from the crossing point J.

Furthermore, as shown in FIG. 6, the vapor dispersion channel Pv is formed in all of up, down, right and left directions from all crossing points J of the widthwise wires 150a and 150b and the lengthwise wires 150c and 150d. Thus, a vapor may be rapidly dispersed in all directions through such channels. In FIG. 6, dispersion paths of the vapor through the vapor dispersion channels Pv are depicted by arrow ' $\leftrightarrow$ '.

A maximum sectional area  $A$  of the vapor dispersion channel Pv is calculated as follows.

$$A = (M + d)d - \pi d^2 / 4$$

As understood from the equations 1 and 2, the maximum sectional area A of the vapor dispersion channel is increased as the mesh number N is decreased and the 5 diameter d of the mesh wire is increased.

However, the maximum sectional area A is different when it is seen in a running direction Y of the widthwise wires 150a and 150b and when it is seen in a running direction X of the lengthwise wires 150c and 150d. It is because tension is changed according to the direction of meshes since the woven screen mesh is woven by fixing the 10 widthwise wires 150a and 150b or the lengthwise wires 150c and 150d firstly and then weaving the other wires thereto like weaving fabrics.

If the coarse mesh 150 shown in FIG. 6 is a screen mesh that is woven with the lengthwise wires 150c and 150d being fixed, the maximum sectional area A of the vapor dispersion channel Pv is larger when seen in X direction than when seen in Y direction.

More specifically, the vapor dispersion channel Pv seen in X direction is shown 15 in FIG. 7, and the vapor dispersion channel Pv seen in Y direction is shown in FIG. 8. Thus, the coarse mesh 150 has a greater vapor dispersion flow rate in X direction than in Y direction. Hereinafter, a direction with a greater vapor dispersion flow rate is called 'a main direction', while a direction with a relatively smaller vapor dispersion flow rate 20 is called 'a sub-direction'. Accordingly, the main direction shows better permeability than the sub-direction since an amount of fluid (vapor or liquid) capable of passing in the main direction is greater than that in the sub-direction under the same pressure.

Considering this fact, when configuring the mesh aggregate G as shown in FIG. 2 or 3, the main direction of the coarse mesh 150 is arranged to be parallel to a heat 25 transfer direction, namely a direction from the heat source 110 to the heat emitting unit

120 in the present invention. Accordingly, a vapor may be rapidly flowed in the heat transfer direction, so the heat transfer performance of the flat plate heat transfer device 100 may be optimized.

Meanwhile, as shown in FIG. 9, while the flat plate heat transfer device is 5 actually operating, a liquid membrane 170 is formed in the vapor dispersion channel Pv positioned at the crossing points J of the widthwise wires and the lengthwise wires of the coarse mesh 150 due to the surface tension of the working fluid. Accordingly, an actual sectional area of the vapor dispersion channel Pv through which the vapor may actually flow is reduced as much as an area occupied by the liquid membrane 170. 10 Here, a ratio of the area of the liquid membrane 170 to the maximum sectional area A of the vapor dispersion channel Pv is decreased as the mesh number N is decreased and the wire diameter d is increased.

If the mesh number N of the coarse mesh 150 is very large and the wire diameter d is very small, the maximum sectional area A of the vapor dispersion channel Pv is 15 significantly decreased to increase flow resistance, and the vapor dispersion channel Pv is blocked by liquid due to surface tension, thereby not allowing vapor to flow therethrough. According to experiments carried out by the inventors, in case of a screen mesh conforming to ASTM specification E-11-95, it may be adopted as a coarse mesh 150 if the mesh number N is in the range of 10 to 60. At this time, if a diameter d 20 of the mesh wire is 0.17 mm or more, there is no difficulty for vapor to flow through the vapor dispersion channel Pv.

According to experiments carried out by the inventors, it is preferred that a wire diameter d of the coarse mesh 150 is 0.17 to 0.5 mm, an opening width M of the mesh is 0.19 to 2.0 mm, and an opening area of the mesh is 0.036 to 4.0 mm<sup>2</sup>.

25 In addition, as shown in FIG. 10, a liquid membrane 170 is also formed by means

of surface tension of the working fluid on a plane at the crossing point J where the widthwise wires 150a and 150b and the lengthwise wires 150c and 150d of the coarse mesh 150 are crossed while the flat plate heat transfer device is operating. This liquid membrane 170 is interconnected to a liquid membrane 170 that is formed at an adjacent 5 crossing point J (see 180 of FIG. 10).

Though not shown in the figures, a liquid membrane is also formed at crossing points of the widthwise wires and the lengthwise wires of the fine mesh 140. In addition, since the fine mesh 140 mainly gives a liquid flow channel as explained later while the heat transfer device is operating, the empty space of the lattice might be fully 10 filled with the liquid membrane.

The connection of the liquid membranes 170 is enabled by control of the width N of the mesh lattice and/or the diameter d of the mesh wire among parameters of the coarse mesh 150, and it also causes horizontal flow of the working fluid by means of capillary force as mentioned below. Thus, though dispersion of the evaporated working 15 fluid is chiefly induced in the coarse mesh 150 through the vapor dispersion channel Pv, horizontal flow of the liquid is also induced therein by means of the capillary force caused in the interconnected liquid membranes 170. At this time, a direction of the horizontal flow is on average opposite to a heat transfer direction. In addition, an amount of the horizontal flow in the coarse mesh 150 is relatively smaller than an 20 amount of horizontal flow of liquid caused through the fine mesh 140.

Referring to FIG. 2 again, while the coarse mesh 150 gives the vapor dispersion channel Pv, the fine mesh 140 gives a liquid flow channel. Accordingly, the working fluid condensed at the heat emitting unit 120 is returned near the heat source 110 through the liquid flow channel. More specifically, in a region of the fine mesh 140 that is 25 approximately right above the heat source 110, evaporation of the working fluid is

continuously induced during the heat transfer procedure. The evaporated working fluid is dispersed through the vapor dispersion channel Pv of the coarse mesh 150 to the heat emitting unit 120 that is kept at a lower temperature than the evaporation point of the working fluid. After that, the working fluid is condensed at a region approximately 5 right below the heat emitting unit 120, and then mainly contained in the liquid membrane of the fine mesh 140.

However, evaporation of the working fluid induced in the region of the fine mesh 140 near the heat source 110 causes deficiency of working fluid, while the working fluid is superfluous in the region of the fine mesh 140 approximately right below the heat 10 emitting unit 120 by means of condensation of the working fluid. Accordingly, capillary force is induced at the interconnected liquid membranes existing in the fine mesh 140, thereby causing continuous flow of the liquid in a direction opposite to a heat transfer direction. That is to say, the fine mesh 140 gives the liquid flow channel so that the working fluid condensed at the region below the heat emitting unit 120 is 15 supplied to the heat source 110. In case of the fine mesh 140, a size of the math lattice is small, so empty spaces of the mesh lattice are filled with liquid by means of the surface tension of the contained working fluid. Accordingly, the fine mesh 140 acts as a liquid flow channel rather than a vapor dispersion channel.

The liquid flow channel of the fine mesh 140 has different maximum sectional 20 areas depending on its direction due to the same reason as the coarse mesh 150. Thus, the fine mesh 140 also has ‘a main direction’ in which a flow rate of the liquid is larger and ‘a sub-direction’ in which a flow rate of liquid is relatively smaller than in the main direction, under the same pressure condition. In the present invention, in order to maximize the heat transfer performance of the flat plate heat transfer device, the mesh 25 aggregate G is preferably configured so that the main direction of the fine mesh 140 is

parallel with the heat transfer direction. In this configuration, both the vapor dispersion efficiency of the coarse mesh 150 and the liquid flow efficiency of the fine mesh 140 are optimized, thereby further improving the heat transfer performance of the flat plate heat transfer device.

5 Considering the function of the fine mesh 140, in case that a screen mesh conforming to ASTM specification E-11-95 is adopted as a fine mesh 140, it is preferred that the mesh number N is in the range of 80 to 400. According to experiments carried out by the inventors, it is preferred that a wire diameter d of the fine mesh 140 is 0.02 to 0.16 mm, an opening width M of the mesh is 0.019 to 0.18 mm, and an opening area of  
10 the mesh is 0.00036 to 0.0324 mm<sup>2</sup>.

In the present invention, a wick structure may be provided to an inner side of the flat case in order to help receiving, condensation and rapid flow of the liquid. Preferably, the wick structure may be made by sintered copper, stainless steel, aluminum or nickel powder. As another example, the wick structure may be made by etching  
15 polymer, silicon, silica (SiO<sub>2</sub>), copper, stainless steel, nickel or aluminum plate.

As an alternative, the flat case may be configured with an electrolytic copper foil that has a rough wick structure with small prominences and depressions about 10 µm on one side but has a smooth surface on the other side. In this case, the surface having a rough wick structure is used as the inner surface of the flat case.

20 Furthermore, it should be understood that various wick structures made using the miromatching method disclosed in US 6,056,044 issued to Benson, et al may be also adopted as the wick structure of the flat case of the present invention.

The flat plate heat transfer device according to the present invention is manufactured to have a thickness of 0.5 to 2.0 mm, or more than 2.0 mm if necessary.

25 In addition, the flat plate heat transfer device may have various shapes such as square,

rectangle, T-shape or the like as shown in FIGs. 11 to 13. In addition, the flat case 130 of the flat plate heat transfer device may be configured with an upper case 130a and a lower case 130b that are separately provided and then assembled as shown in FIGs. 14 and 15, or as an integrated one case as shown in FIG. 16.

5 Preferably, the upper and lower plates 130a and 130b of the flat case 130 may be made of metal, polymer, plastic or the like with a thickness of 0.5 mm or less. The metal may be copper, aluminum, stainless steel, or molybdenum. The polymer may use a polymer material with excellent thermal conductivity like a thermal-conductive polymer. The plastic may also adopt a plastic with excellent thermal conductivity.  
10 The flat case 130 may be made by preparing the upper and lower plates 130a and 130b by cutting any of the aforementioned materials into a desired shape and then uniting them using various manners such as brazing, TIG (Tungsten Inert Gas) welding, soldering, laser welding, electron beam welding, friction welding, and bonding. The united flat case is decompressed to a vacuum or a low pressure and then filled with working fluid  
15 such as water, ethanol, ammonia, methanol, nitrogen or Freon, and then sealed. Preferably, an amount of working fluid filled in the flat case 130 is set in the range of 80 to 150% of wick porosity.

Now, operation of the flat plate heat transfer device according to a preferred embodiment of the present invention is described with reference to FIG. 2.

20 As shown in FIG. 2, one end of the lower plate 130b of the flat plate heat transfer device 100 according to the present invention is adjacent to the heat source 110, and one end of the upper plate 130a is provided with the heat emitting unit 120 such as a heatsink or a cooling fan. In this state, if the temperature of the heat source 110 is increased over the evaporation point of the working fluid, the heat transfer operation is initiated.  
25 More specifically, the heat generated from the heat source 110 is delivered to the fine

mesh 140 through the lower plate 130b of the flat case 130. Then, the working fluid contained in the fine mesh 140 is heated and evaporated, and the evaporated vapor is dispersed in all directions within the flat case 130 through the vapor dispersion channels of the coarse mesh 150. Here, the evaporated working fluid is on average dispersed 5 toward the heat emitting unit 120. At this time, since the main direction of the coarse mesh 150 is coincided with the heat transfer direction, or a direction from the heat source 110 to the heat emitting unit 120, the dispersion of the evaporated working fluid may be optimized.

The dispersed vapor is condensed in the fine mesh 140 and the coarse mesh 150 substantially right below the heat emitting unit 120. The condensation heat generated 10 in this condensation process is delivered to the upper plate 130a of the flat case 130, and then subsequently emitted outward by means of conduction, natural convection, or forced convection by, for example, a cooling fan.

The working fluid in a condensed liquid state is contained in the fine mesh 140 15 and the coarse mesh 150, and then flowed near to the heat source 110 by means of the capillary force caused in the liquid membranes interconnected by continuous evaporation of the working fluid near the heat source 110 so as to be returned to its original position. At this time, the liquid is mainly flowed through the fine mesh 140. The condensed working fluid contained in the coarse mesh 150 is mainly flowed vertically through the 20 crossing points J of the coarse mesh 150 shown in FIG. 10 and then flowed into the fine mesh 140, though it is also flowed horizontally. In an ideal case, such circulation of the working fluid is kept on until the temperature of the heat source becomes substantially equal to or lower than the evaporation point of the working fluid.

In a preferred embodiment, since the main direction of the fine mesh 140 is 25 parallel to the heat transfer direction like the coarse mesh 150, the flow of liquid is also

optimized, thereby supplying the condensed working fluid to a position near the heat source 110 rapidly.

As already known in the above description, the fine mesh 140 plays a role of an evaporation part at a position right above the heat source 110, a role of a condensation part at a position right below the heat emitting unit 120, and a role of an optimized liquid flow channel by means of a capillary force caused in the interconnected liquid membranes as a whole.

In addition, the coarse mesh 150 plays not only a role of an optimized vapor dispersion channel, but also a role of a condensation part at a position right below the 10 heat emitting unit 120 and a role of a returning path so that the liquid condensed at a position right below the heat emitting unit 120 may be flowed vertically to the fine mesh 140 below the coarse mesh 150 and then returned to its original position. In particular, since the coarse mesh 150 plays a role of a vapor dispersion channel, there is no need to form an empty space in the flat case 130 so as to provide a separate vapor dispersion 15 channel.

In the present invention, the mesh aggregate G supports the upper and lower plates 130a and 130b with being interposed between them, so the upper and lower plates 130a and 130b are not crushed while a vacuum is formed for filling of the working fluid or while the device is handled.

According to the present invention, the mesh aggregate G shown in FIG. 2 may have various modifications, which are shown in FIGs. 17 to 23 as examples. Hereinafter, the same component in the drawings is indicated with the same reference numeral.

A flat plate heat transfer device according to another embodiment of the present 25 invention is shown in FIG. 17. Referring to FIG. 17, fine mesh layers 140H and 140L

are formed on inner surfaces of the upper and lower plates 130a and 130b of the flat case 130, and a coarse mesh layer 150 acting as a vapor dispersion channel is interposed between the fine mesh layers 140H and 140L. The fine mesh layer 140H or 140L has at least one layer of fine mesh, as depicted by hatchings, and the coarse mesh layer has at 5 least one layer of coarse mesh, as depicted by dots.

For example, in case that the lower plate 130b is contacted with the heat source 110 and the heat emitting unit 120 is provided to the upper plate 130a, the vapor evaporated from the lower fine mesh layer 140L contacted with the lower plate 130b is dispersed in all directions through the vapor dispersion channels of the coarse mesh layer 10 150 and then preferably condensed into a liquid with emitting heat at the upper fine mesh layer 140H contacted with the upper plate 130a. Since the fine mesh layer 140H or 140L has a relatively larger mesh number N than the coarse mesh layer 150, the number 15 of condensation points where the vapor may be condensed is accordingly increased, thereby improving the heat emitting efficiency. In addition, the coarse mesh layer 150 gives a returning channel so that the working fluid condensed at the upper fine mesh layer 140H may flow to the lower fine mesh layer 140L.

Preferably, the main directions of the coarse mesh layer 150 and the fine mesh layers 140H and 140L are arranged to be parallel with the heat transfer direction, thereby optimizing vapor dispersion and liquid flow.

20 FIG. 18 shows still another embodiment of the present invention, wherein at least one layer of fine mesh 140M is provided in at least a part of the coarse mesh layer 150 interposed between the fine mesh layers 140H and 140L so as to interconnect the fine mesh layers 140H and 140L for giving a liquid flow channel between them. This makes the working fluid, condensed at the upper fine mesh layer 140H with emitting heat, 25 be more easily moved to the lower fine mesh layer 140L.

Preferably, the main directions of the coarse mesh layer 150 and the fine mesh layers 140H, 140M and 140L are arranged to be parallel with the heat transfer direction, thereby optimizing vapor dispersion and liquid flow.

According to the present invention, it is also possible that different kinds of mesh layers that have at least three kinds of different mesh numbers are provided in complex, as shown in FIG. 19 as an example. In the heat transfer device of FIG. 19, a fine mesh layer 140 having at least one layer of fine mesh is provided on the inner surface of the lower plate 130b of the flat case 130 that is adjacent to the heat source 110 so as to deliver heat to the liquid to be evaporated, and a coarse mesh layer 150 having at least one layer of coarse mesh is provided on the fine mesh layer 140 so as to give a dispersion channel for the evaporated working fluid. In addition, on the inner surface of the upper plate 130a of the flat case 130 to which the heat emitting unit 120 is adjacently positioned, an intermediate mesh layer 140' having at least one layer of intermediate mesh whose mesh number is relatively larger than the coarse mesh and relatively smaller than the fine mesh is provided. Here, the intermediate mesh layer 140' further improves delivery efficiency of the condensation heat of the vapor.

Preferably, the main directions of the coarse mesh layer 150, the fine mesh layer 140 and the intermediate mesh layer 140' are arranged to be parallel with the heat transfer direction, thereby optimizing vapor dispersion and liquid flow.

Furthermore, as shown in FIG. 20, at least one layer of additional intermediate mesh layer 140" for interconnecting the intermediate mesh layer 140' and the fine mesh layer 140 may be further provided in at least a part of the coarse mesh layer 150 interposed between the intermediate mesh layer 140' and the fine mesh layer 140 in order to give a liquid flow channel for the working fluid condensed at the intermediate mesh layer 140' toward the fine mesh layer 140. Though not shown in the figure, the

additional intermediate mesh layer 140" may be replaced with the fine mesh layer 140.

FIGs. 21 to 23 show a flat plate heat transfer devices according to still another embodiment of the present invention. FIG. 22 is a plane sectional view taken along B-B' line of FIG. 21, and FIG. 23 is a side sectional view taken along C-C' line of FIG. 22.

- 5 The flat plate heat transfer device of this embodiment is more suitably adopted as a flat plate heat pipe.

Referring to FIGs. 21 to 23, a fine mesh layer 140 is provided in the flat case 130 at a position adjacent to the heat source 110, and an intermediate mesh layer 140' is provided therein near the heat emitting unit 120 where a working fluid is condensed with emitting heat. In addition, the fine mesh layer 140 and the intermediate mesh layer 140' are interconnected by means of a coarse mesh layer 150. Here, the fine mesh layer 140 acts as an evaporation part of the working fluid, the coarse mesh layer 150 acts as a flow channel of vapor, and the intermediate mesh layer 140' acts as a condensation part of the working fluid. Thus, the working fluid is evaporated by means of the heat delivered from the heat source 110 to the fine mesh layer 140, and the vapor is flowed to the intermediate mesh layer 140' through the vapor dispersion channel of the coarse mesh layer 140. Subsequently, the vapor is condensed at the intermediate mesh layer 140' with emitting heat to the heat emitting unit 120. The condensed working fluid in a liquid state is returned again to the evaporation part through the fine mesh layer 140 by 20 means of capillary force.

Preferably, the main directions of the coarse mesh layer 150, the fine mesh layer 140 and the intermediate mesh layer 140' are arranged to be parallel with the heat transfer direction, thereby optimizing vapor dispersion and liquid flow.

- According to this embodiment, in order to promote condensation heat transfer and 25 prevent the vapor dispersion channels from being blocked by formation of liquid

membranes, vapor flow spaces 200 (see FIGs. 22 and 23) are preferably formed in the intermediate mesh layer 140 so that the vapor introduced from the coarse mesh layer 150 may flow through them. In this case, the vapor passing through the coarse mesh layer 150 is further dispersed everywhere into the intermediate mesh layer 140', so 5 condensation efficiency and heat emitting efficiency may be further improved.

As an alternative, the intermediate mesh layer 140' may be replaced with the fine mesh layer 140. In this case, vapor flow spaces identical to the intermediate mesh layer 140' may also be formed in the fine mesh layer 140. Furthermore, the vapor flow space is not limited to this embodiment, but it may be suitably designed in the flat case to 10 communicate with the coarse mesh so that the vapor passing through the vapor dispersion channels of the coarse mesh may be guided to the vapor condensation part of the fine mesh layer 140 right below the heat emitting unit 120.

#### Experimental Example

15 Inventors prepared upper and lower plates of a flat case as shown in FIG. 15 with the use of an electrolytic copper foil with a thickness of 0.1 mm, and then mounted a mesh aggregate, which is configured so that one coarse mesh is interposed between two fine meshes as shown in FIG. 17, in the flat case so as to make three types of flat plate heat transfer devices as shown in the following table 1.

20

Table 1

	Coarse Mesh	Fine Mesh
Type 1 (sample 1)	Main direction	Sub-direction
Type 2 (sample 2)	Main direction	Main direction
Type 3 (sample 3)	Sub-direction	Main direction

The samples 1, 2 and 3 were respectively 120 mm, 50 mm and 1.3 mm in width,

length and height, and the mesh used is a copper screen mesh in which a content of copper is at least 99%. The coarse mesh had a wire diameter  $d$  of 0.225 mm, a mesh thickness of 0.41 mm and a mesh number of 15, while the fine mesh layer had a wire diameter  $d$  of 0.11 mm, a thickness of 0.22 mm and a mesh number of 100. The upper  
5 and lower plates of the flat case were sealed by means of denatured acrylic binary bond (HARDLOC<sup>TM</sup>, made by DENKA in Japan) with leaving a working fluid injection hole. Before the working fluid is injected, the inside of the flat case was decompressed to  $1.0 \times 10^{-7}$  torr with the use of a rotary vacuum pump and a diffusion vacuum pump, and then the flat case was filled with distilled water as a working fluid, and then finally sealed.

10 After the samples 1 to 3 were prepared as mentioned above, a copper heat source with width and length of 12 mm respectively was attached to a left portion of the lower plate of the flat case of each sample and a heatsink was installed to a right portion of the upper plate of the flat case of each sample as shown in FIG. 17. After that, the heatsink was forcibly cooled with the use of a fan. In this state, a temperature of the center of  
15 the heat source was measured with supplying energy to the heat source, and thermal resistance of each sample was calculated according to the following equation 3 with the use of a temperature difference between the heat source and the ambient. The calculated results are shown in FIG. 24.

20 Equation 3

$$\text{Total Thermal Resistance} = (T_{\text{measured temperature}} - T_{\text{ambient temperature}})/(Q_{\text{input power}})$$

Referring to FIG. 24, it may be found that the sample 2 in which the main directions of both the fine mesh and the coarse mesh are all set in parallel to the heat  
25 transfer direction shows most excellent heat transfer performance. In addition, the

sample 1 shows better heat transfer performance than the sample 3, and it should be considered that the direction of the coarse mesh gives dominant effects on the heat transfer performance rather than the direction of the fine mesh. Thus, the heat transfer device according to the present invention in which vapor dispersion and liquid flow are 5 optimized may be a good choice for a heat transfer unit for cooling an electronic equipment owing to its excellent heat transfer performance.

#### INDUSTRIAL APPLICABILITY

According to the present invention, it is possible to manufacture a flat plate heat 10 transfer device with a thin thickness, and various shapes. In particular, the method of the present invention does not require MEMS process or etching process that need a lot of costs, and it is possible to provide a flat plate heat transfer device at low costs with the use of inexpensive mesh and case. Furthermore, since the mesh provided in the cooling device prevents the case from being distorted or crushed during the vacuum-forming 15 process or after the device is manufactured, the device may have improved reliability. In addition, since the vapor dispersion channels and the liquid flow channels are optimized for effective heat transfer, the flat plate heat transfer device of the present invention shows high heat transfer performance. The flat plate heat transfer device of the present invention may be efficiently used to cool various electronic equipments such 20 as a mobile electronic terminal.